Current advances in membranes for competent hydrogen purification: A mini review

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Abstract. Hydrogen (H_2) has been extensively accepted as a clean and efficient energy carrier to alleviate the mounting global energy and environmental crisis. Therefore, an ever-increasing demand for high-quality hydrogen provides a strong driving force towards developing efficient hydrogen purification technologies. Membrane-based gas separation technology for hydrogen purification has attracted considerable attention owing to the inherent advantages over other conventional separation techniques. Benefited from the booming development of chemical science, materials science and membrane science, an increasing number of advanced membrane materials and membranes have been developed for hydrogen purification in recent years. It is anticipated that the present review will provide the guidance for the future research and development of membrane materials and membranes for hydrogen purification, and hence promote the development of sustainable and clean hydrogen energy.

Keywords: Hydrogen purifications, Gas separation, materials characteristic, sustainable energy.

1 Introduction

In the present years, H_2 is a top-notch transporter for clean energy which draws in refreshed and regularly expanding concern around the globe generally because of the progression of power cells, ecological loads along with worldwide environmental alteration issues (1-3). Enhancement and separation innovations are imperative in the thermochemical procedures of H_2 creation from petroleum products (4). The membrane reactors show dependable affirmations in transferring the harmony at whatever point the transfer response of water–gas associated with converting monoxide into H_2

(5). Membranes are additionally vital in the accompanying refinement of H_2. Generally, there are two inorganic membrane classifications in the cleansing and generation of H_2: metal alloy and thick segment metal, including porous ceramic membrane. Sol-gel or hydrothermal method are utilized in manufacturing porous ceramic membrane for elevated consistency and toughness in high temperature, hydrothermal conditions and severe pollutants, for example, microporous membrane which exhibit affirmations in gas transfer response at high temperatures.

Fig. 1 shows Palladium-based membrane for H_2 purification (6). Eminent importance of separation innovation in diverse parts of synthetic and energy enterprises is broadly recognised. In a way, a primary development will be accomplished by the advancing of technologies related to the separation of aerosolised species (7). This may be because of a high fossil-fuel request in addition to the interest for several gases for pharmaceutical and industrial applications (8). For instance, it determined that in the fossil-fuel derivative segment alone 41 of the established gas sources inside the US are sub-quality which should be updated through the expulsion of exorbitant carbonic acid gas, H_2S, N_2 with different polluting influences so as to satisfy the well-head procedure or pipeline transmission necessities (9). A comprehensive investigation ponders are carried out on current strategies paying little heed to different setup gas separation technologies present, for example, pressure swing sorption and fluid ingestion so as to detected procedures with abilities to offer expense-effective task and less complicated management (10). Membranes innovation has been a possible option for numerous uses of gas separation mostly because of its multiple benefits, for example, little footprint, simple scale-up and high energy strength (11).

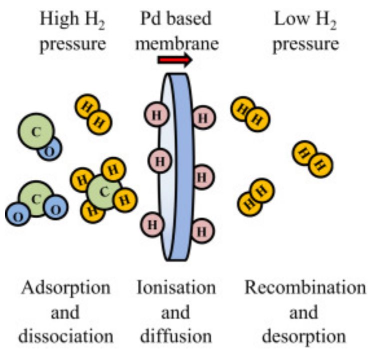

Fig. 1. Palladium-based membrane for H_2 purification (4).

As indicated by the referred accounts, following in the year of 2002, the gas separation membrane innovation has turned into a $150million/year business with the prospect to develop in the coming years (5). Therefore, a comprehensive discovery of R&D membrane innovation development is required so as to conquer the hindrances. Beside high calibre, economically accessible membrane composed of a chemical compound, carbon membranes offer an utterly remarkable and engaging membranes class with recognised determinations along with excellent gas separation performance. Carbon membranes contribute striking attribute with excellent thermal and compound strength beside the capacity to exceed the permeability– selectivity exchange off. Carbon membranes have an inkling by taking the lead in acknowledgement and appearance of morphology in separation performance. This is bolstered by the porous structure which permits high penetrability as a result of high profitability while conservative size and segregation of molecules structure result in high selectivity which given by the molecular sieving system.

2 Membrane-based H_2 Purification

Hydrogen has been extensively accepted as a clean and efficient energy carrier to alleviate the mounting global energy and environmental crisis. Therefore, an ever-increasing demand for high-quality hydrogen provides a strong driving force towards developing efficient hydrogen purification technologies. Membrane-based gas separation technology for hydrogen purification has attracted considerable attention owing to the inherent advantages over other conventional separation techniques (6). Benefited from the booming development of chemical science, materials science and membrane science, an increasing number of advanced membrane materials and membranes have been developed for hydrogen purification in recent years (6). It is anticipated that the present review will provide the guidance for the future research and development of membrane materials and membranes for hydrogen purification, and hence promote the development of sustainable and clean hydrogen energy. As a relatively new and rapidly developing technology, membrane technology exhibits inherent advantages of energy-efficiency, cost-effective and environmental compatibility compared to conventional separation techniques. Moreover, membrane technology can be facilely coupled with other separation techniques to enhance the efficiency and economics of separation process. Nowadays, membrane technology has been widely used in water treatment, meanwhile it has also commercialized for air separation, natural gas sweetening and hydrogen recovery from ammonia purge gas. With the rapid development of hydrogen economy and membrane science, membrane-based gas separation technology shows great potential for the hydrogen purification market as well. Great demands for high-quality hydrogen products provide the driving force for research and development of advanced membrane materials and membranes for hydrogen purification (7).

2.1 H_2-selective membranes

Several review articles presented on membrane technology for hydrogen purification merely introduced H_2-selective membranes or polymeric membranes. Furthermore, the majority of these reviews were involved in the research achievements before 2010 besides an in-depth review about the application of polymeric and ionic liquid based membranes for biohydrogen purification in 2013 (12). To the best of our knowledge, there is no comprehensive review available so far to focus specially on recent advances in membrane-based technology for hydrogen purification. Hydrogen energy has been widely considered as a promising energy in the future, which greatly pushes forwards the innovation of separation techniques for high-quality hydrogen production. Membrane-based gas separation technology has exhibited inherent advantages over conventional separation techniques for hydrogen purification. Therefore, an increasing number of advanced membranes made from various materials including inorganic materials, polymers and organic–inorganic hybrid materials, have been successfully developed via different novel membrane fabrication methods, some of which have already showed favorable performances for H_2–CO_2 separation expectedly. Several representative low-cost membrane materials (e.g. PEO-based copolymers and polyvinylamine) with excellent solution processing properties have been fabricated into large-area composite membranes with high performances. Moreover, carbon molecular sieve hollow fiber membranes and TR polymer hollow fiber membranes have been prepared. Furthermore, the corresponding membrane modules have been manufactured. In particular, Proteus™ and Polaris™ membrane modules have been successfully used on the membrane-based demonstration system for CO_2 removal from shifted synthesis gas. Regarding the type of materials, hydrogen separation membranes may be classified into the following categories: polymeric membranes, porous membranes, dense metal membranes and proton conducting membranes. The most important parameters when comparing membranes are the perm-selectivity, the flux and the temperature range at which the membranes can be applied. Membranes are basically barriers that allow the flow of some components of a feed gas mixture stream. The stream containing the components that permeate through the membrane is called permeate and the stream containing the retained components is called retentate. Membranes for hydrogen separation should have the following characteristics; high selectivity towards hydrogen, high flux, low cost, and high mechanical and chemical stability. **Fig. 2** shows H_2 separation by syngas system (12).

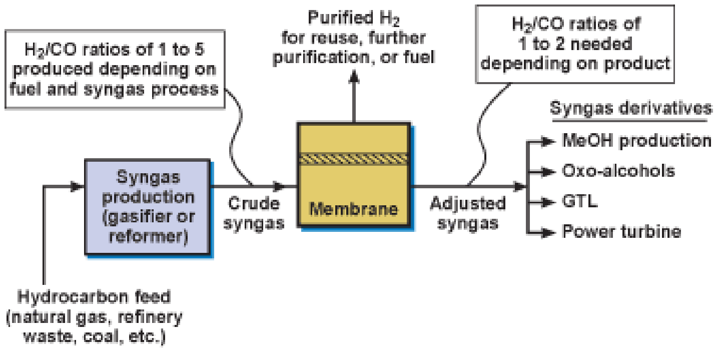

Fig. 2. H_2 separation by syngas system (12).

Sustainable and clean energy development has become a major global issue in terms of the world's energy shortage and environmental problem. However, fossil fuels are still expected to be the predominant resource of energy by preference in the near term (next 5–20 years or even more) despite that an increasing number of renewable energies have received considerable attention over the several decades. Therefore, it is of great importance and impendency to develop more efficient ways to utilize these limited fossil fuels for sustainable development. Hydrogen has been widely considered to be an attractive energy carrier and storage medium with high efficiency for developing a cost-effective, environmental-benign and sustainable energy system, because it possesses distinct advantages of high gravimetric energy density (1.43×10^8 J/kg) and low greenhouse gas emission (9). In addition, hydrogen is an important feedstock with increasing demands for the chemical industries. Hence, about 53 million metric tons of hydrogen worldwide was produced annually, and the hydrogen market valued at $88 billion in 2010 (13). **Fig. 3** illustrates hydrogen as fuel system.

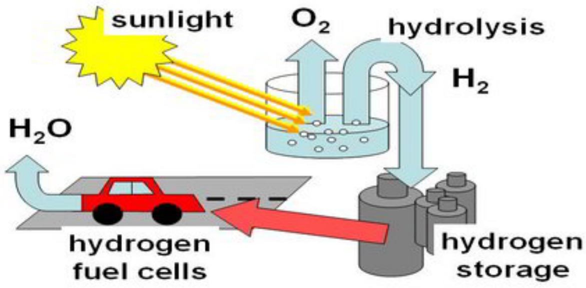

Fig. 3. H_2 as fuel system (13).

Conclusion

From the viewpoint of practical applications, the systematic investigations of effects of temperature, pressure, contaminants on membrane performances were rare. Therefore, the feasibility study of membrane materials and the corresponding membranes for hydrogen purification should be carried out to push forward the industrialization. Altogether, a variety of advanced membrane materials and membranes have significantly promoted the development of membrane-based technology for hydrogen purification. We believe that the literatures published to date donate excellent examples for future exploitation of membrane materials and membranes for hydrogen purification (14-16). With the rapid development of chemical science, materials science and membrane science, membranes with excellent separation performances and favorable operational stability which could meet the requirements of practical application in hydrogen purification, are expected to be developed in the near future.

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